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# Applied Meteorology Unit (AMU) Quarterly Report



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## Executive Summary

*This report summarizes the Applied Meteorology Unit (AMU) activities for the fourth quarter of Fiscal Year 2006 (October - December 2007). A detailed project schedule is included in the Appendix.*

### Task      Objective Lightning Probability Tool: Phase II

**Goal**      Update the lightning probability forecast equations used in 45th Weather Squadron (45 WS) operations with new data and create a graphical user interface (GUI) in the Meteorological Interactive Data Display System (MIDDS) that automatically gathers the data needed as input to the equations developed in Phase I of this task. The new data may improve the performance of the equations, and the automated tool will increase forecaster efficiency.

**Milestones**      Calculated 10 stability parameters from the Cape Canaveral Air Force Station (CCAFS) sounding (XMR) to be used as candidate predictors in the equation development. Began developing equations with new predictors and data sets.

**Discussion**      Preliminary results from the equation development show that the flow regime lightning probability was the second-most important predictor of lightning occurrence in all five warm season months. The most important predictors for each month were one of the XMR stability parameters.

### Task      Peak Wind Tool for General Forecasting

**Goal**      Develop a tool to forecast the peak wind speed for the day from the surface to 300 ft on Kennedy Space Center (KSC)/CCAFS during the cool season (October – April). The tool should be able to forecast the timing of the peak wind speed and the background average wind speed, based on observational data available for the 45 WS 0700L weather briefing.

**Milestones**      Acquired data from the KSC/CCAFS wind tower network for four cool seasons, October 2002 – April 2006. The database includes 5-minute average and peak wind speed and direction observations from 47 wind towers at altitudes from 12 to 495 ft. Completed a preliminary analysis of tower peak wind speeds on days when the morning radiosonde observation (RAOB) indicated a surface-based temperature inversion.

**Discussion**      The tower-peak-wind-speed-of-the-day (TPWSD) exceeded 35 kt on 57 of 466 days (12.2%) with surface-based temperature inversions. A comparison between the TPWSD and the wind speed profile from the morning RAOB showed that the TPWSD exceeded the highest wind speed in the lowest 5000 ft of the morning RAOB on 51 of the 57 days. This result was somewhat unexpected, based on general forecast guidelines.

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## Executive Summary, *continued*

### Task      Stable Low Cloud Phase II: Nocturnal Event Feasibility Study

**Goal**      Conduct a study on rapidly-developing low cloud ceiling events at the Shuttle Landing Facility (SLF) during the nighttime hours in the cool season months and determine if representative meteorological conditions can be identified to assist in forecasting these events. Cloud ceilings are one of the greatest forecast challenges identified by Spaceflight Meteorology Group (SMG) and 45 WS forecasters. The ability to forecast low cloud ceilings at night will improve support to nighttime shuttle launches and landings.

**Milestones** Analyzed infrared satellite imagery for 86 possible rapidly developing stable low cloud events that occurred in the years 2000 to 2005. Assessed the atmospheric characteristics of the rapidly developing events and the non-events, and completed the final report.

**Discussion** Of the 86 possible events, only 6 were considered to be stable low cloud events with rapid cloud development. Composite results of the meteorological characteristics of the 6 events and 80 non-events indicated no distinguishable characteristics between them.

### Task      Situational Lightning Climatologies for Central Florida, Phase II

**Goal**      Create the climatological probability of lightning occurrence and mean number of strikes for each flow regime as in Phase I for the two 12-hour periods 0000–1200 and 1200–2400 UTC, and in 5-, 10-, 20-, and 30-n mi circles surrounding the SLF in 1-, 3-, and 6-hour increments. The 12-hour climatologies will be used by the forecasters at the National Weather Service in Melbourne, FL (NWS MLB) to update their daily lightning threat index map. The SLF climatologies will aid in the aviation forecast requirements at NWS MLB, and provide a tool to SMG that will assist them in making forecasts for Flight Rule violations of lightning occurrence during a shuttle landing.

**Milestones** Reviewed the documents describing the results from Phase I, and began reviewing the FORTRAN code that will be modified for Phase II.

**Discussion** The code modification will begin in the next quarter.

### Task      Anvil Threat Corridor Forecast Tool in AWIPS

**Goal**      Migrate the Anvil Threat Corridor Forecast Tool from MIDDS to the Advanced Weather Interactive Processing System (AWIPS). This tool is used in launch and landing operations to determine the threat from natural or triggered lightning due to flight through anvil cloud. The SMG is depending more on AWIPS for operations and the 45 WS plans to replace MIDDS with AWIPS. The 45 WS and SMG requested that the AMU transition the anvil tool to AWIPS to ensure it will remain available for operations.

**Milestones** Tested the anvil forecast tool after installing it on the AWIPS systems at the AMU and SMG. Wrote a report that described all bugs and needed improvements discovered during testing.

**Discussion** The AMU and SMG conducted extensive testing of the tool. It was modified based on that testing, resulting in a much-improved product. Most of the software bugs were related to improper data initialization and incorrect map labels.

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**Executive Summary, *continued***

**Task** Volume Averaged Height Integrated Radar Reflectivity (VAHIRR)

**Goal** Transition the VAHIRR algorithm into operations using NWS Weather Surveillance Radar 1988 Doppler (WSR-88D) data. The previous lightning launch commit criteria (LLCC) for anvil clouds to avoid triggered lightning were restrictive and lead to unnecessary launch delays and scrubs. The VAHIRR algorithm was developed as a result of the Airborne Field Mill program as part of a new LLCC for anvil clouds. This algorithm will assist forecasters in providing fewer missed launch opportunities with no loss of safety compared with the previous LLCC.

**Milestones** Installed and configured all of the necessary software to produce VAHIRR radar products in real-time, using a live radar data feed in the 45 WS, SMG, and AMU. Wrote a VAHIRR installation guide and test plan. Assisted SMG in creating an automated procedure that will send VAHIRR radar products to AWIPS in real-time.

**Discussion** The test plan describes how the VAHIRR radar product will be tested for accuracy, reliability, and efficiency. The results will help determine whether the product is ready to be used in launch operations. The 45 WS and SMG provided feedback on the test plan and it is in the process of being updated based on that feedback. After the test plan is approved by the AMU, SMG, and 45 WS, the test will be conducted in the AMU.

**Task** Weather Research and Forecasting (WRF) Model Sensitivity Study

**Goal** Conduct several WRF sensitivity case studies to determine the best configuration to use operationally at SMG and NWS MLB for predicting warm season convective initiation. Determining the best model configuration will assist forecasters in their short-term thunderstorm forecasting for the general public and evaluating flight rules and launch commit criteria.

**Milestones** Compiled and archived data for five convective initiation and two non-convective initiation days with different flow regimes over East Central Florida. Completed all Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS)/ Advanced Research WRF (ARW) model runs within the WRF- Environmental Modeling System (EMS) framework. Continued to install and configure the Local Analysis and Prediction System (LAPS) software to initialize the WRF model.

**Discussion** Five convective initiation and two non-convective initiation days were chosen to run tests on each combination of the WRF initializations. The next step is completing all model runs for the ADAS/ Non-hydrostatic Mesoscale Model (NMM) configuration. Work continues on converting raw satellite data to a form ingestible by LAPS. Conversion of all other data to a form ingestible by LAPS is complete.

## Special Notice to Readers

Applied Meteorology Unit (AMU) Quarterly Reports are now available on the Wide World Web (www) at <http://science.ksc.nasa.gov/amu/>.

The AMU Quarterly Reports are also available in electronic format via email. If you would like to be added to the email distribution list, please contact Ms. Winifred Lambert (321-853-8130, [lambert.winifred@ensco.com](mailto:lambert.winifred@ensco.com)). If your mailing information changes or if you would like to be removed from the distribution list, please notify Ms. Lambert or Dr. Francis Merceret (321-867-0818, [Francis.J.Merceret@nasa.gov](mailto:Francis.J.Merceret@nasa.gov)).

## Background

The AMU has been in operation since September 1991. Tasking is determined annually with reviews at least semi-annually. The progress being made in each task is discussed in this report with the primary AMU point of contact reflected on each task.

## AMU ACCOMPLISHMENTS DURING THE PAST QUARTER

### SHORT-TERM FORECAST IMPROVEMENT

#### Objective Lightning Probability Tool: Phase II (Ms. Lambert)

The 45th Weather Squadron (45 WS) forecasters include a probability of lightning occurrence in their daily morning briefings. This information is used by personnel involved in determining the possibility of violating launch commit criteria (LCC), evaluating flight rules (FR), and planning for daily ground operation activities on Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). The AMU developed a set of logistic regression equations that calculate the probability of lightning occurrence in Phase I of this task (Lambert and Wheeler 2005). These equations outperformed several standard forecast methods used in operations. The graphical user interface (GUI) developed in Phase I allows forecasters to interface with the equations by entering parameter values to output a probability of lightning occurrence. The forecasters must gather data from the morning sounding and other sources, then manually input that data into the GUI. The 45 WS requested that a tool be developed on the Meteorological Interactive Data Display System (MIDDS) that retrieves the required parameter

values automatically for the equations to calculate the probability of lightning for the day. This will reduce the possibility of human error and increase efficiency, allowing forecasters to do other duties. The 45 WS requested that warm season data from the years 2004 and 2005 be added to the Phase I 15-year 1989–2003 data set. They also requested modifications to the data that are input to the equations in the hope of improving their accuracy.

#### Predictors

Ms. Lambert calculated 10 stability and moisture parameters from the 1000 UTC CCAFS (XMR) soundings that were used as candidate predictors in the equation development. They are

- Total Totals (TT),
- Cross Totals (CT),
- K-Index (KI),
- Lifted Index (LI),
- Thompson Index (TI; KI – LI),
- Severe Weather ThrEAT (SWEAT) Index,
- Showalter Index (SI),
- Temperature at 500 mb ( $T_{500}$ ),
- Mean Relative Humidity in the 825–525 mb layer ( $RH_{85}$ ), and
- Precipitable Water up to 500 mb (PW).

These were added to the three predictors described in the last AMU Quarterly Report (FY06 Q4) for a total of 13 candidate predictors:

- Daily climatological lightning frequency,
- 1-day persistence, and
- Flow regime lightning probability.

#### ***Equation Development and Testing***

Ms. Lambert also began developing the new logistic regression equations using the procedure described in the Phase I final report (Lambert and Wheeler 2005). The preliminary results show that the flow regime lightning probability was the second-most important predictor of lightning

#### **Peak Wind Tool for General Forecasting (Dr. Short and Ms. Lambert)**

The expected peak wind speed for the day is an important element in the daily morning forecast for ground and space launch operations at KSC and CCAFS. The 45 WS must issue forecast advisories for KSC/CCAFS when they expect peak gusts to exceed 35 kt, 50 kt, and 60 kt thresholds at any level from the surface to 300 ft. However, the 45 WS forecasters indicate that peak wind speeds are a challenging parameter to forecast, regardless of their value. They requested that the AMU develop a tool that will help them forecast the daily average and highest peak non-convective wind speed, and the timing of the peak speed, from the surface to 300 ft on KSC/CCAFS for the cool season (October-April). The AMU will use a 4-year database of high resolution soundings and other observational data available by the morning weather briefing at 0700 local time to develop a tool that provides a forecast of the peak wind speed for the day, its timing, and the average wind speed at the time of the peak.

#### ***AFWA Meteorological Techniques***

The Air Force Weather Agency (AFWA) publication on Meteorological Techniques (AFWA 2005) provides general guidelines on forecasting surface wind speed in Chapter 1, Section III. One method of particular interest for this task involves an analysis of the morning sounding to forecast wind speed later in the day. The guidelines suggest that low-level temperature inversions can shield the surface from higher wind speeds aloft until the inversion breaks due to surface heating. One guideline reads as follows: "If winds increase above the inversion (and the inversion is below 5,000 feet), expect maximum gusts during

occurrence in all months. The most important predictor for June, July, and August was TI. For May and September, the most important predictors were KI and RH<sub>85</sub>, respectively. In the Phase I set of equations, persistence and the daily climatology were important predictors for every month. In the current study, persistence was chosen as a predictor in all months except August, and the daily climatology was only chosen for May, August, and September. More tests will be done to determine the final predictor set for each month.

Contact Ms Lambert at 321-853-8130 or [lambert.winnie@ensco.com](mailto:lambert.winnie@ensco.com) for more information.

maximum heating to be 80 percent of the 5,000 feet wind speed." This AFWA publication also provides the caveat that this and other guidelines are only general estimates. Actual values may differ widely due to local terrain, and should be determined locally from forecast studies.

#### ***Wind Tower Network Data***

Dr. Short acquired a 4-year database of 5-minute wind tower data from Mr. Wahner of Computer Sciences Raytheon (CSR). The data are from the cool seasons in the period 1 October 2002 – 10 April 2006 and include average and peak wind speed and direction observations from the 47 towers in the KSC/CCAFS network. The analysis was restricted to the cool season, October – April, and to the 34 towers used by the 45 WS to verify Weather Watches, Weather Advisories, and wind observations from levels at and below 300 ft. The combination of wind tower data and XMR morning radiosonde observations (RAOBs), discussed in the previous AMU Quarterly Report (Q4 FY06), resulted 703 days available for the analysis. This represents 85% of the 829 days in the period.

The wind tower data were quality controlled (QC) using a simplified algorithm, pending the development of an improved AMU wind tower QC process. The simplified QC excluded any wind speed reports where the peak speed was more than 2.5 times greater than the average wind speed. The factor of 2.5 was adopted from the previous AMU QC process.

#### ***Initial Analysis of Wind Tower Data***

Dr. Short performed an initial analysis of the wind tower data on days for which the high-resolution (100-ft) sounding data showed the existence of a surface-based temperature

inversion. Approximately 65% of the available morning soundings had a surface-based inversion where the temperature at the 100 ft level was higher than the surface temperature. However, on only about 12% of those days did the tower peak-wind-speed-of-the-day (TPWSD) exceed 35 kt.

Figure 1 shows the maximum wind speeds observed in the lowest 5000 ft from the XMR RAOB versus the TPWSD for all days with a surface-based temperature inversion. The TPWSD frequently exceeded the RAOB maximum speed and almost always exceeded 80% of its value. The wind tower data have not yet been screened for convective events. Convective event screening will likely eliminate some of the high peak wind speed events, but convective events in the cool season are rare.

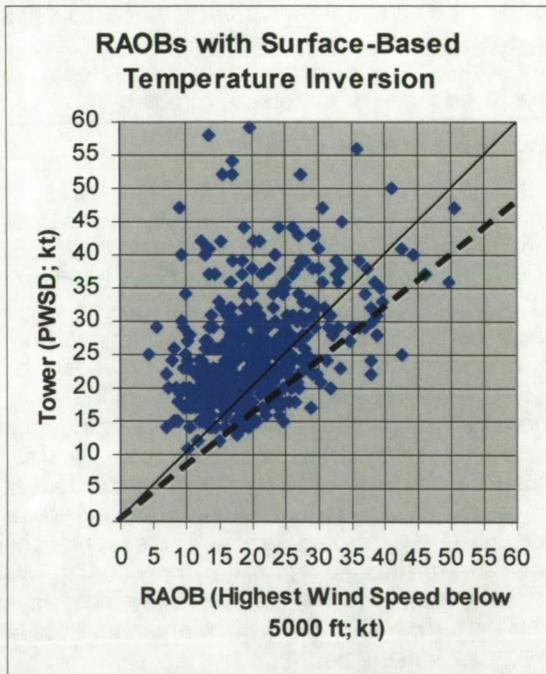


Figure 1. Highest wind speed (kt) in the lowest 5000 ft of the morning RAOB vs. peak wind-speed-of-the-day for cool season profiles with a surface-based inversion. The dashed line represents an 80% rule-of-thumb for estimating the TPSWD from the RAOB.

Figure 2 shows the time of occurrence of the TPWSD for days with a surface-based temperature inversion. The TPWSD usually

occurred in the early afternoon at 1800 UTC (1300 local), just after the time of maximum surface heating. There was also a secondary maximum of occurrence just after 1200 UTC (0700 local) just after sunrise.

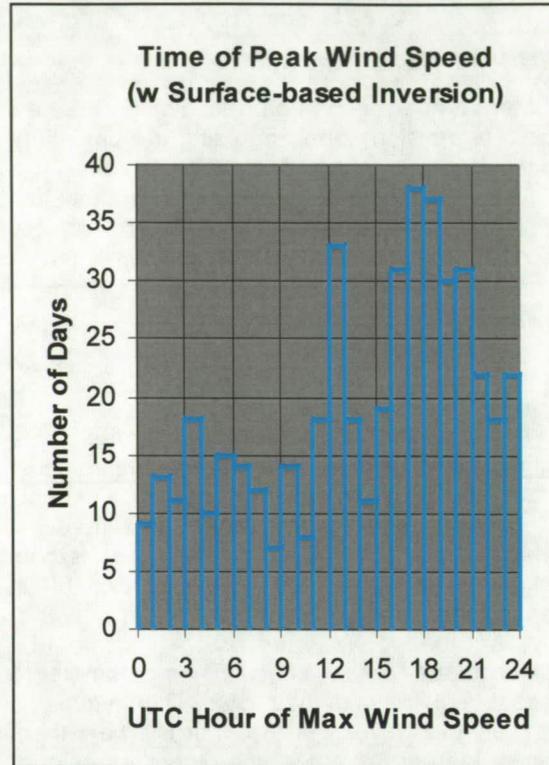


Figure 2. Time of peak wind speed vs. number of occurrences on days with surface-based temperature inversions.

Dr. Short and Ms. Lambert will investigate wind speed data from the morning XMR RAOB and the tower network on KSC/CCAFS to determine characteristics of the near-surface environment that accompany peak wind speed events. They will also incorporate synoptic analyses and surface observations from the Shuttle Landing Facility to screen out convective events and to identify large-scale features and trends in the pressure and wind fields.

Contact Dr. Short at [short.david@ensco.com](mailto:short.david@ensco.com) or 321-853-8105 for more information.

## **Stable Low Cloud Phase II: Nocturnal Event Feasibility Study (Mr. Barrett and Dr. Bauman)**

For all shuttle missions, the Spaceflight Meteorology Group (SMG) issues 30 to 90 minute forecasts for low cloud ceilings at the Shuttle Landing Facility (SLF). Cloud ceilings are one of the greatest forecast challenges identified by SMG forecasters, especially rapid ceiling development below 8000 ft in a stable environment. The first phase of this work (Wheeler and Case 2005) analyzed the onset, location, and dissipation times of low clouds in a stable environment during daylight hours for the cool season months of November through March. The AMU determined that the mean inversion height and strength were similar between event and non-event days, while the mean relative humidity was slightly higher on the event days. The main discerning factor between the event and non-event days was the wind profile. On 85% of the event days the winds veered with height through 8000 ft, while the winds veered with height on only 17% of the non-event days. The objective of Phase II is to determine if representative meteorological conditions can be identified that are conducive for the sudden development of low cloud ceilings in the nighttime during the cool season months. If such conditions can be identified, they will be used to support cloud ceiling forecasts for nighttime shuttle launches and landings.

### **Analysis Results**

Mr. Barrett and Dr. Bauman completed their analysis of SLF surface observations and radiosonde data. After they received the additional satellite imagery that Mr. Barrett ordered from the NOAA Comprehensive Large Array-data Stewardship System (CLASS), Dr. Bauman analyzed infrared satellite imagery for the 86 possible events that they identified. Examination of the satellite imagery was the only way to distinguish between an in-place rapidly developing low ceiling and cloud advection. Mr. Barrett first restored locally archived infrared satellite imagery onto MIDDs, then loaded the CLASS satellite imagery onto MIDDs. All imagery was viewed with MIDDs software and images were saved in JPEG format. After examining loops of the satellite imagery on MIDDs, Dr. Bauman identified only 6 of the possible 86 events as rapid low ceiling formation events. The remaining 80 were clearly advection situations.

It is important to note that it was difficult to analyze nighttime infrared satellite imagery since low clouds tend to be close to the same temperature as the ground. Dr. Bauman found this to be true regardless of the color enhancement used. However, he found it much easier to identify advection cases than in-place rapid low ceiling development cases.

In the first phase of this work (Case and Wheeler 2005), which considered only daytime events, nearly 30% of the 68 possible daytime events were identified as rapid low ceiling development cases. In contrast, only 7% of all nighttime possible low-ceiling events were identified as rapidly-developing events. The other 93% were identified as advection situations. This implies that nighttime rapidly developing low cloud events do not occur very often, and certainly not as often as the daytime events.

### **Event Characteristics**

The meteorological characteristics of the six nighttime events are given in Table 1. The inversion strengths in Table 1 may be underestimates of the actual magnitudes because the sounding data interpolated to 1000 ft levels were used to obtain the values. In some instances, the inversions may have been less than 1000 ft deep and the interpolated sounding data may have smoothed out the magnitude of the inversions, especially for those based above the surface. Because there were only six events, any statistics generated from the data in Table 1 would not be considered robust or significant.

Dr. Bauman compiled composite values of the meteorological parameters for all 86 possible events to compare and contrast the events and non-events. Table 2 shows a summary of meteorological parameters for the 6 events versus 80 non-events. Unfortunately, there are no significant distinguishable characteristics between the events and non-events. However, the vertical wind profile from the surface to 15,000 ft indicates a veering wind profile 83% of the time for events and 61% of the time for non-events. Such a profile represents a warm advection pattern that favors rising motion, and thus, cloud formation in a moist environment. Therefore, when a clear cloud advection event is not in progress, a forecaster should be aware of the fact that nighttime rapid low cloud development is more likely to occur with winds veering with height.

**Table 1. Summary of the 6 rapid low ceiling development events and their meteorological characteristics. The mean quantity of relative humidity (RH) is given for all levels at and below the inversion, if one existed. The wind direction change with height was determined by examining the sounding data from the surface to 15,000 ft.**

Event Date	Onset Time (UTC)	Dissipation Time (UTC)	Highest Inversion Height (ft)	Inversion Strength (°C)	Mean RH (%)	Δ Wind Direction w/Height
01/29/2002	0200	0400	none	-	-	veering
11/12/2002	1038	1400	5000	1.1	92	backing
11/27/2003	0545	0700	none	-	-	veering
01/08/2004	0215	0600	4000	3.7	84	veering
03/11/2005	1100	1600	4000	2.1	89	veering
11/12/2005	1004	1500	6000	2.7	82	veer → back

**Final Report**

Dr. Bauman and Mr. Barrett completed the final report for this task. They are awaiting final approval from NASA in order to distribute the report, and expect to do so in January 2007.

Contact Mr. Barrett at 321-853-8205 or [barrett.joe@ensco.com](mailto:barrett.joe@ensco.com) or Dr. Bauman at 321-853-8202 or [bauman.bill@ensco.com](mailto:bauman.bill@ensco.com) for more information.

**Table 2. The meteorological parameters associated with the 6 event and 80 non-event cases.**

Parameter	Events	Non Events
Frequency of inversions	67%	76%
Mean inversion base height of highest inversion	5000 ft	4400 ft
Mean inversion strength of highest inversion	2.5°C	2.1°C
Mean RH below highest inversion	87%	79%
Frequency of events with winds veering with height	83%	61%

**Situational Lightning Climatologies for Central Florida, Phase II (Dr. Bauman)**

The threat of lightning is a daily concern during the warm season in Florida. Recent research has revealed distinct spatial and temporal distributions of lightning occurrence that are strongly influenced by large-scale atmospheric flow regimes. In Phase I, Ms. Lambert created gridded lightning density and frequency climatologies based on the flow regime that the forecasters at the National Weather Service in Melbourne, FL (NWS MLB) use to issue daily lightning threat maps for their county warning area (Lambert et al. 2006). Phase II of this work consists of three parts. In the first part, Dr. Short created climatological soundings of wind speed, wind direction, temperature, and dew point at Jacksonville (JAX), Tampa (TBW), Miami (MFL),

and XMR for each of eight flow regimes from a 16 year database of soundings (Short 2006). In the second part of the Phase II work, Dr. Bauman will calculate the same climatologies as in Phase I for the two 12-hour periods 0000–1200 UTC and 1200–2400 UTC. In the third part of the Phase II work, Dr. Bauman will create the flow regime climatologies for 5-, 10-, 20-, and 30-n mi circles around the SLF as shown in Figure 3 in 1-, 3-, and 6-hour increments. The 5- and 10-n mi circles are consistent with the aviation forecast requirements at NWS MLB. The code from this task will be delivered to them so they can create the climatologies for the other airports at which they have forecast responsibilities. The 20- and 30-n mi circles at the SLF were chosen to create the climatologies that will assist SMG in making forecasts for FR violations of lightning occurrence during a shuttle landing.

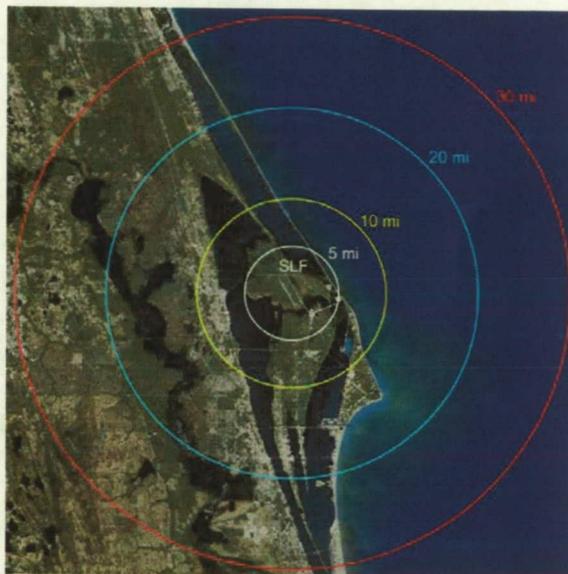
Dr. Bauman will modify the code used in Phase I to create the climatologies for the 12-hour periods. The changes to the code will be minor in order to output the 0000–1200 UTC and 1200–2400 UTC periods. He will also modify the Phase I code to create the SLF climatologies, but these modifications will be more extensive. The new algorithms need to determine the indices of the grid boxes that comprise the requested circles sizes centered on the SLF. Once determined, the number of lightning strikes in all the boxes will be summed to create one value for the total number of lightning strikes in the circle. The climatology calculations in the code will remain the same. Instead of a grid of values, one value each for the probability of lightning occurrence and the mean number of strikes per flow regime will be created for each circle.

Dr. Bauman reviewed the previous work conducted in Phase I of this task. He then worked with Ms. Lambert to review of the FORTRAN code that he will modify to create the 12-hour climatologies. They also developed a plan to modify the code and develop new algorithms for the SLF climatologies that consist of the following main goals:

- Update the algorithms to determine the grid point indices of the grid boxes comprising the various circles sizes centered on the SLF,

- Sum the number of lightning strikes in all of the boxes within each circle, and
- Output a probability of lightning occurrence and mean number of strikes in each flow regime for each circle.

Contact Dr. Bauman at 321-853-8202 or [bauman.bill@ensco.com](mailto:bauman.bill@ensco.com) for more information.



**Figure 3. Satellite image of KSC/CCAFS area with 5-, 10-, 20-, and 30- n mi range rings centered on the SLF.**

## **INSTRUMENTATION AND MEASUREMENT**

### **Anvil Forecast Tool in AWIPS (Mr. Keen, Mr. Barrett, and Dr. Bauman)**

The forecasters at SMG and 45 WS have identified anvil forecasting as one of their most challenging tasks when predicting the probability of LCC or FR violations due to the threat of natural or triggered lightning. In response, the AMU developed an anvil threat corridor graphic that can be overlaid on satellite imagery using the MIDDs. This tool helps forecasters estimate the location of thunderstorms that might produce an anvil threat 1, 2, and 3 hours into the future. It has been used extensively in launch and landing operations. The SMG is depending more on the Advanced Weather Interactive Processing System (AWIPS) during operations and the 45 WS has plans to replace their MIDDs with AWIPS. To ensure it will remain available for operations, the forecasters tasked the AMU to transition the anvil

tool from MIDDs to AWIPS. The AMU will also create a GUI to ensure easy access to the tool.

Mr. Keen completed the initial development of the GUI and wrote software installation instructions for the anvil forecast tool. Dr. Bauman completed a first draft of the User's Guide and distributed it to SMG and the 45 WS for review. Mr. Barrett installed Anvil Forecast Tool on the AWIPS system at the AMU and Ms. Hood installed the software at SMG. Mr. Barrett, Dr. Bauman, and personnel at the SMG conducted extensive testing on the tool to determine its performance. From the testing results, Mr. Barrett created a "bug" report listing all GUI issues and requested improvements. He fixed most of the bugs, and made the GUI more user-friendly. Some of the bug fixes were related to improper variable initialization and incorrect labels on the graphical overlay map.

The anvil forecast tool program can use observed sounding data, KSC 50 MHz wind profiler data and model forecasts from the Rapid Update Cycle (RUC), Weather Research and

Forecasting (WRF) and Global Forecast System (GFS) models to calculate the layer-averaged wind velocity. It also contains code that determines the latitude/longitude points to plot the graphical threat sector in AWIPS. The GUI code, layer-averaged wind velocity calculation, and latitude/longitude plotting routine make up the AWIPS Anvil Forecast Tool.

The anvil forecast tool GUI is accessible from the Tools dropdown menu in AWIPS (Figure 4). When the tool is selected, the GUI in Figure 5 is displayed. In the GUI, the user can select from three data source types for the wind velocity calculations:

- Observed sounding data (RAOB),
- Model forecasts (Models), or
- KSC 50-MHz wind profiler data (50 MHz).

After selecting the data source type, the user then makes three selections:

- Date and time (Date-Time),
- Site location for the display (Site), and
- Location of the data source (Station or Forecast Hour).

When the Date-Time is chosen, The Site and Station lists are populated. When these three selections have been made, the tool automatically calculates the layer averaged wind velocity as shown in the lower text area in Figure 6.

The user has the option of creating a new map with the Make button, or adding a new graphic to an existing map with the Append

button. Figure 7 shows the resulting anvil threat graphic for the settings chosen in Figure 6 using the Make button. Figure 8 shows an anvil threat sector for Tampa using the Tampa sounding added to the XMR sector in Figure 7. It is also possible to overlay the RAOB, 50 MHz, and Models maps in one image. Figure 9 shows anvil threat sectors created from model and profiler data overlaid on the threat sector in Figure 7.

Contact Mr. Barrett at 321-853-8205 or [barrett.joe@ensco.com](mailto:barrett.joe@ensco.com), or Dr. Bauman at 321-853-8202 or [bauman.bill@ensco.com](mailto:bauman.bill@ensco.com) for more information on this task.

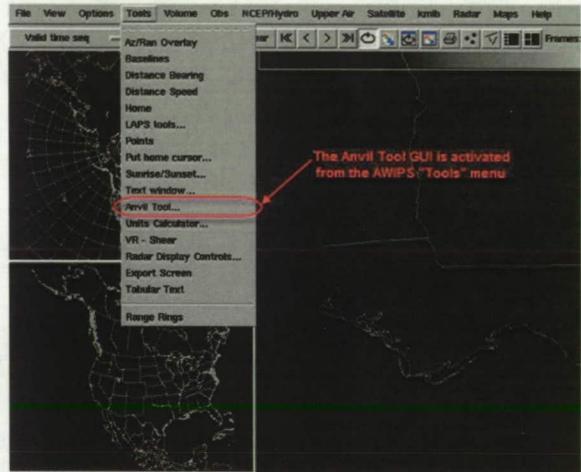


Figure 4. The Anvil Tool GUI is accessed from the "Tools" dropdown menu on the AWIPS Main Menu.

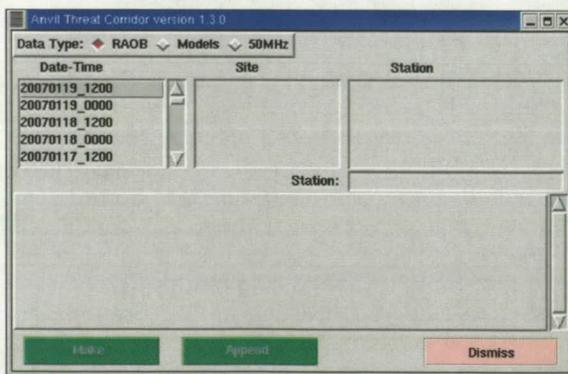


Figure 5. This is the GUI that is displayed when the Anvil Tool GUI is selected in the AWIPS Tools dropdown menu.

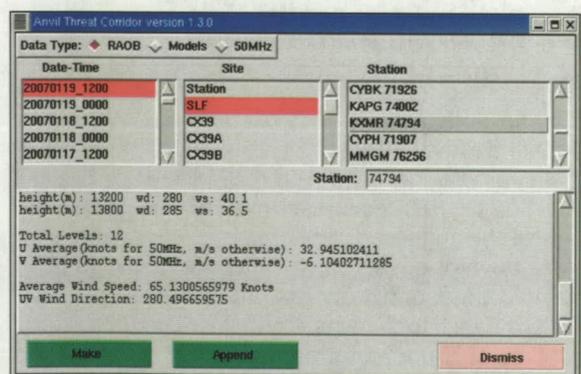


Figure 6. Display of the layer-averaged wind velocity (lower text area) for the XMR RAOB at 1200 UTC on January 19, 2007 in the GUI.

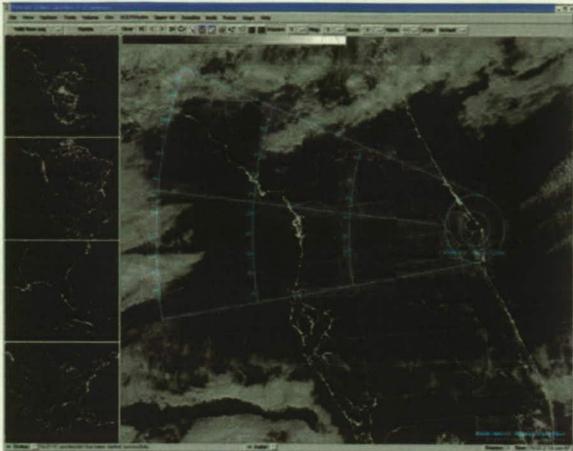


Figure 7. AWIPS display showing the anvil threat sector based on the XMR sounding, created with the Make button.

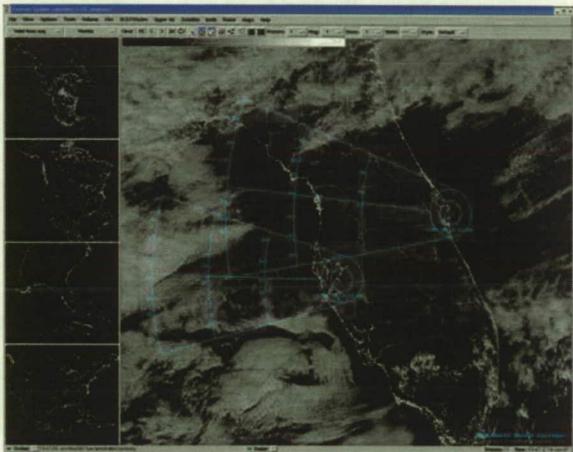


Figure 8. AWIPS display showing the anvil threat sector based on the XMR and TBW soundings, created with the Append button.

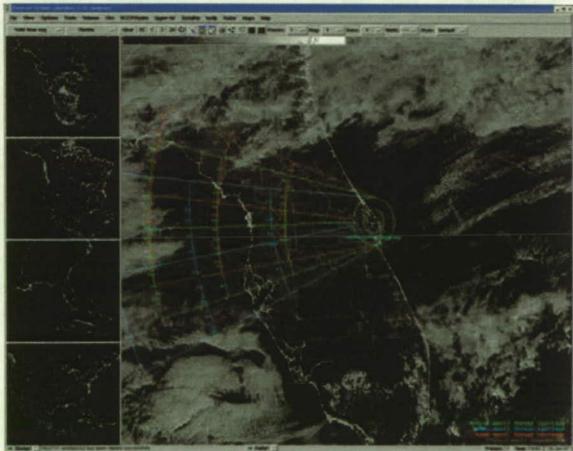


Figure 9. AWIPS display showing three anvil threat sectors using model, XMR sounding, and 50-MHz profiler data centered on the SLF.

### Volume Averaged Height Integrated Radar Reflectivity (VAHIRR) Algorithm (Mr. Keen, Ms. Miller, Mr. Gillen, and Dr. Merceret)

Lightning LCC (LLCC) and FR are used for all launches and landings, whether Government or commercial, using a Government or civilian range (Willett et al. 1999). These rules are designed to avoid natural and triggered lightning strikes to space vehicles, which can endanger the vehicle, payload, and general public. The current LLCC for anvil clouds, meant to avoid triggered lightning, have been shown to be overly restrictive. They ensure safety, but falsely warn of danger and lead to costly launch delays and scrubs. A new LLCC for anvil clouds, and an associated radar algorithm needed to evaluate that new LLCC, were developed using data collected by the Airborne Field Mill research program managed by KSC (Dye et al. 2006). Dr. Harry Koons of Aerospace Corporation conducted a performance analysis of the VAHIRR algorithm from a safety perspective. The results suggested that the LLCC based on this algorithm would assist forecasters in providing a lower rate of missed launch opportunities with no loss of safety compared with the previous LLCC.

Mr. Barrett and Ms. Miller completed the installation and configuration of an Open Radar Product Generator (ORPG) clone machine at the AMU. The ORPG-clone is a RedHat Linux machine that has the Common Operations and Development Environment (CODE) and ORPG software installed. The CODE and ORPG software are used to develop and test new algorithms for the NWS Weather Surveillance Radar 1988 Doppler (WSR-88D). The Unidata Local Data Manager (LDM) program and compiled VAHIRR source code were also installed on the AMU's ORPG-clone. The ORPG-clone can be used to create the VAHIRR radar product using a live feed of Level II data from the NWS MLB WSR-88D. Mr. Barrett wrote the VAHIRR Installation Guide, which describes how to install all the software associated with the ORPG-clone as well as how to install the VAHIRR software. He also assisted with the installation of ORPG-clones at SMG and 45 WS. With assistance from Mr. Barrett, SMG created an automated procedure to send VAHIRR radar products to AWIPS.

Mr. Barrett, Ms. Miller, Dr. Merceret, and Dr. Bauman wrote a VAHIRR test plan that describes how the VAHIRR radar product will be tested for accuracy, reliability, and efficiency. The results of the test will help determine whether the VAHIRR radar product is ready to be used in launch operations. The AMU subsequently received feedback on the test plan from SMG and the 45 WS. Mr. Barrett is in the process of updating the test plan based on that feedback. After the test plan is approved by the AMU, SMG, and 45 WS, the test will be carried out using the AMU's ORPG-clone.

To create VAHIRR radar products in real-time, the user first starts up the LDM program, which begins the feed of radar data into the user's Linux workstation. Next, the user starts the ORPG program so that radar products can be created with the incoming radar data. A program called read\_ldm is executed next, which automatically

feeds the VAHIRR radar algorithm with live radar data. Radar products, including VAHIRR, are then created automatically. To view radar products, the user enters "cvg" at a terminal window to start the CODEview Graphics (CVG) application. On the main page of CVG, the user can view a list of all the VAHIRR products in the database by typing "153" in the entry box labeled "Pcode", and selecting the Update List and Filter buttons (Figure 10). An individual VAHIRR product (Figure 11) can be viewed by selecting the product from the VAHIRR product list.

For more information on this task, contact Ms. Miller at [miller.juli@ensco.com](mailto:miller.juli@ensco.com) or 321-783-9735 ext. 221; Mr. Gillen at 321-783-9735 ext. 210 or [gillen.robert@ensco.com](mailto:gillen.robert@ensco.com); Mr. Barrett at 321-853-8205 or [barrett.joe@ensco.com](mailto:barrett.joe@ensco.com), or Dr. Merceret at [Francis.J.Merceret@nasa.gov](mailto:Francis.J.Merceret@nasa.gov) or 321-867-0818.

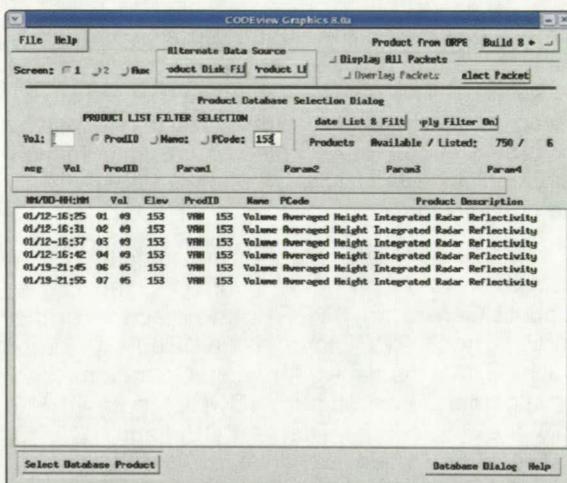


Figure 10. Main page of the CODEview Graphics application. The product list has been filtered to only show the VAHIRR radar products. The left-most column shows the date and time of product creation.

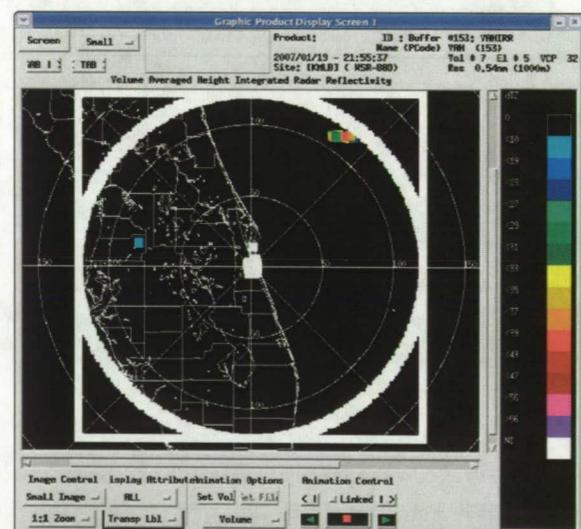


Figure 11. VAHIRR output product centered over East Central Florida. The VAHIRR values in the legend at right have units dBZ-kilofeet.

## MESOSCALE MODELING

### Weather Research and Forecasting (WRF) Model Sensitivity Study (Dr. Watson)

The WRF model is the next generation community mesoscale model designed to enhance collaboration between the research and operational sectors. The SMG and the NWS MLB are moving forward with implementing the WRF model operationally into their AWIPS systems. The WRF model has two dynamical cores – the Advanced Research WRF (ARW) and the Non-hydrostatic Mesoscale Model (NMM). There are also two options for the initialization of the WRF model – the Local Analysis and Prediction System (LAPS) and the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS). Having a series of initialization options and WRF cores, as well as many options within each core, provides SMG and NWS MLB with a lot of flexibility as well as challenges. This includes determining which configuration options are best to address specific forecast concerns. The goal of this task to assess the different configurations available and to determine which configuration will best predict warm season convective initiation. To accomplish this, the AMU was tasked to

- Compare the WRF model performance using ADAS versus LAPS for the ARW and NMM model cores,
- Compare the impact of using a high-resolution local forecast grid with 2-way, 1-way, and no nesting, and
- Examine the impact of assimilating soil moisture sensor data on WRF model performance.

#### ADAS/WRF Model Configuration

Dr. Watson chose five convective initiation days based on the timing of the onset of convection, the flow regime of the day, and availability of data. During the months July-September, twenty days were missing data. Of the days with available data, she examined 34 as potential convective initiation days. Of the 34, she chose 5 as convective initiation days, and 2 as null cases, or non-convective initiation days.

Code fixes for the “hot-start” initialization of the WRF Environmental Modeling System (EMS) were made available to the public in December from the Cooperative Program for Operational Meteorology, Education, and Training (COMET).

Dr. Watson downloaded and installed the upgraded software to the local cluster. Scripts written by Mr. Case were used to initialize the WRF model with output from ADAS. This suite of scripts formed the core for running ADAS to initialize the WRF-EMS. Dr. Watson completed all model runs using ADAS to initialize the WRF-ARW core within the WRF-EMS framework. Each model run created 12 hour forecasts with three runs per day, at 0900, 1200, and 1500 UTC. She used data from the 40-km North American Model (NAM) for the initial and boundary conditions.

Figure 12 shows the three-hourly composite reflectivity from an ADAS/ARW simulation at 1200 UTC 2 September 2006, and Figure 13 shows the corresponding three-hourly images of WSR-88D Level II radar reflectivity data. A preliminary comparison between the two figures shows that the ADAS/ARW model spins up too much convection during the first three hours of the simulation. In particular, it develops too much precipitation over the central and southern areas of the Florida peninsula and over the Gulf of Mexico. It also fails to capture the area of strong precipitation directly northwest of Grand Bahama Island. By forecast hours 6 to 9, the model does a reasonable job of simulating the convection over the peninsula. Dr. Watson will continue to run the ADAS/WRF configuration of the NMM core for the convective initiation and null case days.

#### LAPS/WRF Model Configuration

Dr. Watson is continuing the process of setting up and configuring the LAPS software. The largest task in configuring LAPS is working with the ingest code. This ingest code is only supported if the raw data has the same configuration and format as the NOAA Earth System Research Laboratory Global Systems Division's (GSD) raw data. Dr. Watson configured and tested software she received from GSD to convert raw WSR-88D Level II radar data to Network Common Data Form (NetCDF) format and software to convert model Gridded Binary (GRIB) data to NetCDF format. She also wrote code to convert the available surface data to a form ingestible by LAPS.

Dr. Watson corresponded with personnel from GSD and the University of Wisconsin about the issue of converting raw satellite data to NetCDF format for ingest into LAPS. She is still working to resolve this issue.

For more information, contact Dr. Watson at [watson.leela@ensco.com](mailto:watson.leela@ensco.com) or 321-853-8264.

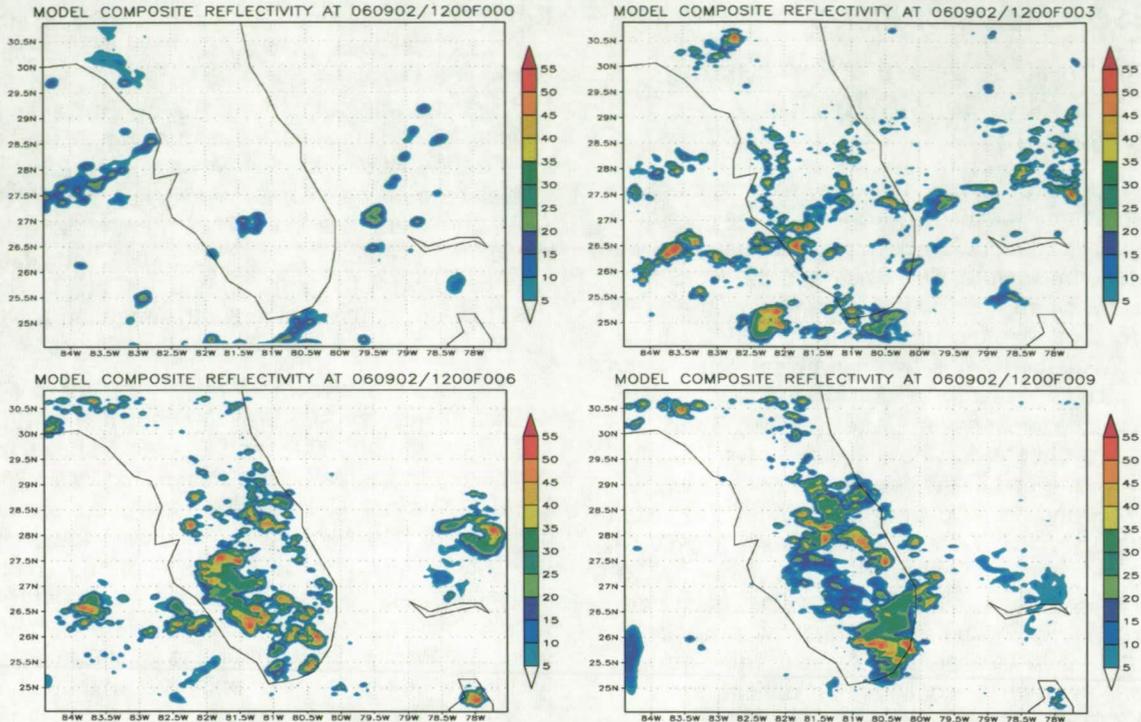


Figure 12. ADAS/ARW forecast composite reflectivity from the 1200 UTC 02 September model run, with valid times at (a) 1200 UTC, (b) 1500 UTC, (c) 1800 UTC, and (d) 2100 UTC. Units in DbZ.

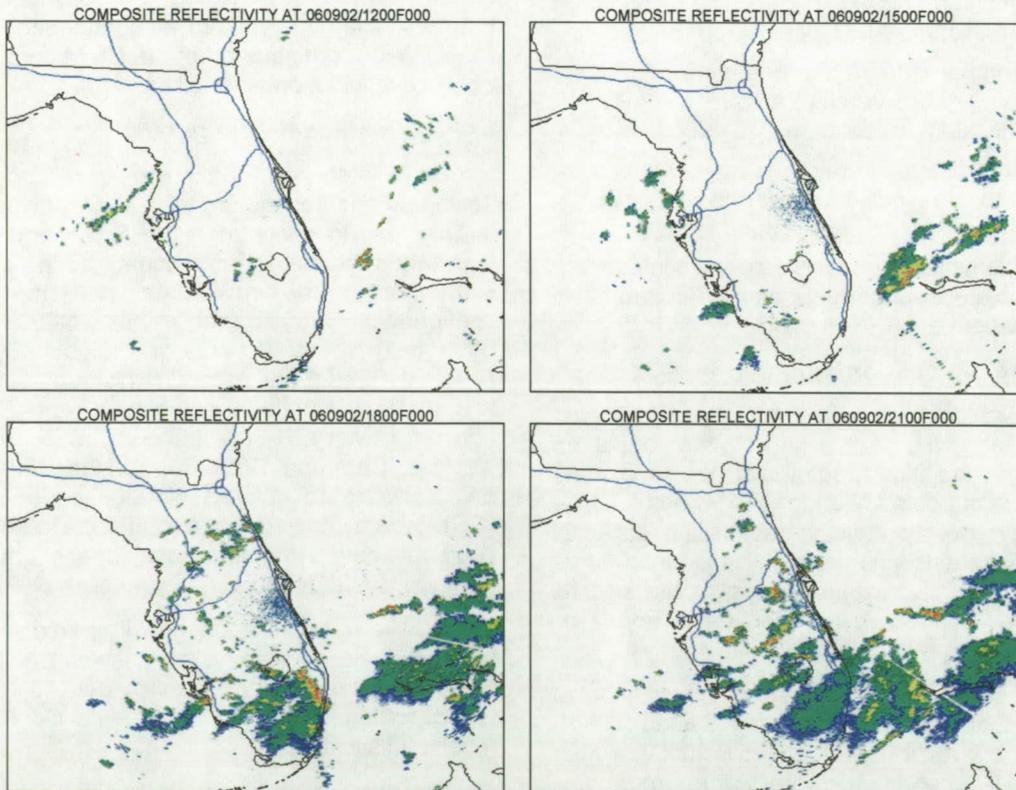


Figure 13. WSR-88D Level II radar data displays from 02 September 2006 at (a) 1200 UTC, (b) 1500 UTC, (c) 1800 UTC, and (d) 2100 UTC. The shaded areas are in units of DbZ.

### AMU CHIEF'S TECHNICAL ACTIVITIES (Dr. Merceret)

Dr. Merceret and the Airborne Field Mill (ABFM) science team held a teleconference to develop an action plan for additional analysis of ABFM data that could lead to further LLCC revisions. He began examining ABFM data relating to the behavior of electric fields external to electrified anvil clouds to determine the possibility of safety reducing the stand-off distances in the LLCC. He also made revisions to a manuscript he prepared for the Journal of Applied Meteorology that presents ABFM data relating to the magnitude of the electric field as a function of distance from cloud edge.

Dr. Merceret and ENSCO, Inc. personnel conducted temperature-controlled vacuum

chamber tests of GEMSTONE sensors at the KSC engineering laboratories. This work was done under the GEMSTONE contract, not the AMU contract. GEMSTONE is a NASA-ENSCO collaboration to develop miniaturized disposable solar-powered balloon-sondes that can remain at a constant altitude for days while reporting standard radiosonde variables to the ground via satellite.

Dr. Merceret attended the *Weather Radar Replacement Project Kickoff Meeting* representing NASA and the KSC Weather Office. He also worked VAHIRR issues related to the AMU VAHIRR task and STS-116 operations.

### AMU OPERATIONS

Current and former AMU team members were awarded the 2006 National Weather Association (NWA) Larry R. Johnson Award (Figure 14). This award is presented to an individual or a group for recognition of unique events or extraordinary accomplishments that significantly contributed to operational meteorology. Ms Lambert, Dr. Short, Dr. Bauman, and Dr. Merceret are the current members on the award team, and Mr. Wheeler and Mr. Case are the former AMU members who were also named in the award.



Figure 14. Current and former AMU team members accepting the Larry R. Johnson Award at the NWA Annual Meeting. From left to right, Ms. Lambert, Mr. Case, Dr. Bauman, and NWA President Dave Knapp.

Dr. Bauman, Ms. Lambert, and Dr. Watson attended the NWA Annual Meeting in Cleveland, OH during 16-19 October 2006. Dr. Bauman presented two posters describing the RSA/Legacy

peak wind speed comparison and nighttime stable low cloud tasks. Ms. Lambert gave a presentation describing the results from both phases of the flow regime lightning climatology task.

The AMU submitted three extended abstracts for the 87th American Meteorological Society Annual Meeting which will be held in San Antonio, TX from 14-18 January 2007. Dr. Short submitted his extended abstract to the 14th Symposium on Meteorological Observations and Instrumentation describing the comparison of peak wind speeds between the RSA and Legacy wind sensors. Ms. Lambert and Dr. Bauman submitted their extended abstracts to the 16th Conference on Applied Climatology describing both phases of the flow regime lightning climatology task and Phase II of the stable low cloud task, respectively.

Dr. Bauman and Dr. Watson supported the Delta II STEREO launch. Ms. Lambert supported the Delta II GPS launch and the STS-116 launch attempt on 7 December. Mr. Barrett supported the STS-116 launch on 9 December. Dr. Short supported the STS-116 landing at KSC on 21 December at KSC. Dr. Watson traveled to Johnson Space Center (JSC) and observed SMG support of the STS-116 launch/landing operations 6-7 December. Dr. Merceret was on hand in support of all launches and the landing.

Dr. Bauman, Mr. Barrett and Mr. Gillen attended the *Weather Radar Replacement Project Kickoff Meeting* to address concerns or questions about the VAHIRR algorithm. Mr. Barrett submitted the AMU's FY07 IT budget and Dr. Merceret approved it.

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## List of Acronyms

30 SW	30th Space Wing	MIDDS	Meteorological Interactive Data Display System
30 WS	30th Weather Squadron	MSFC	Marshall Space Flight Center
45 RMS	45th Range Management Squadron	NAM	North American Mesoscale model
45 OG	45th Operations Group	NASA	National Aeronautics and Space Administration
45 SW	45th Space Wing	NCAR	National Center for Atmospheric Research
45 SW/SE	45th Space Wing/Range Safety	NetCDF	Network Common Data Form
45 WS	45th Weather Squadron	NMM	Non-hydrostatic Mesoscale Model
ABFM	Airborne Field Mill Experiment	NOAA	National Oceanic and Atmospheric Administration
ADAS	ARPS Data Analysis System	NSSL	National Severe Storms Laboratory
AFSPC	Air Force Space Command	NWS	National Weather Service
AFWA	Air Force Weather Agency	NWS MLB	NWS in Melbourne, FL
AMU	Applied Meteorology Unit	ORPG	Open Radar Product Generator
ARPS	Advanced Regional Prediction System	QC	Quality Control
ARW	Advanced Research WRF	RAOB	RAdiosonde OBservation
AWIPS	Advanced Weather Interactive Processing System	RH	Relative Humidity
CCAFS	Cape Canaveral Air Force Station	RH <sub>85</sub>	RH in the 825–525 mb layer
CLASS	Comprehensive Large Array-data Stewardship System	RSA	Range Standardization and Automation
CODE	Common Operations and Development Environment	SLF	Shuttle Landing Facility
CSR	Computer Sciences Raytheon	SMC	Space and Missile Center
EMS	Environmental Modeling System	SMG	Spaceflight Meteorology Group
FR	Flight Rules	SPoRT	Short-term Prediction Research and Transition
FSU	Florida State University	SRH	NWS Southern Region Headquarters
FY	Fiscal Year	TBW	Tampa, FL 3-letter identifier
GSD	Global Systems Division	TI	Thompson Index
GUI	Graphical User Interface	TPWSD	Tower Peak Wind Speed of the Day
JAX	Jacksonville, FL 3-letter identifier	USAF	United States Air Force
JSC	Johnson Space Center	UTC	Universal Coordinated Time
KI	K-Index	VAHIRR	Volume Averaged Height Integrated Radar Reflectivity
KSC	Kennedy Space Center	WRF	Weather Research and Forecasting Model
LAPS	Local Analysis and Prediction System	WSR-88D	Weather Surveillance Radar 1988 Doppler
LCC	Launch Commit Criteria	XMR	CCAFS 3-letter identifier
LDM	Local Data Manager		
LLCC	Lightning LCC		
McBASI	McIDAS BASIC Language Interpreter		
McIDAS	Man Computer Interactive Data Access System		
MFL	Miami, FL 3-letter identifier		

## Appendix A

AMU Project Schedule 31 January 2007				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date <i>(New End Date)</i>	Notes/Status
Forecasting Low-Level Convergent Bands Under Southeast Flow	Develop standard data/graphics archive	Apr 05	Apr 05	Completed
	procedures to collect real-time case study data			
	Collect data real-time during southeast flow days	Apr 05	Jan 06	Completed - Delayed due to customer request to collect more winter cases
	Data analysis	Jul 05	Feb 06	Completed - Delayed as above
	Final report	Feb 06	Mar 06 <i>(Oct06)</i>	Completed - Delayed as above
Objective Lightning Probability Phase II	Begin developing the MIDDS tool with McBAS1	Dec 05	Feb 06	Completed - Delayed due to final software corrections
	Calculate new forecast parameters	Jan 06	Feb 06 <i>(Oct06)</i>	Completed Delayed due to delays in Lightning Climatology task
	Develop and test new equations	Mar 06	Apr 06 <i>(Feb 07)</i>	Delayed as above
	Update the MIDDS tool with new equations	Apr 06	Apr 06 <i>(Feb 07)</i>	Delayed as above
	Final report	Mar 06	May 06 <i>(Mar 07)</i>	Delayed as above

AMU Project Schedule 31 January 2007				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date ( <i>New End Date</i> )	Notes/Status
Peak Wind Tool for General Forecasting	Data collection: wind towers, XMR 100-ft soundings, 915-MHz profilers	Sep 06	Oct 06 ( <i>Jan 07</i> )	Delayed to obtain 915-MHz profiler data
	Software development: wind tower data QC, sounding inversion detection, 915 MHz total power display	Sep 06	Dec 06 ( <i>Jan 07</i> )	Delayed to modify the AMU wind tower QC software
	Data analysis	Dec 06	Feb 07	On Schedule
	Interim evaluation	Feb 07	Mar 07	On Schedule
	Forecast tool development, if approved	Mar 07	May 07	On Schedule
	Final report	Jun 07	Jul 07	On Schedule
Stable Low Cloud Phase II: Nocturnal Events	Data Collection: surface obs, soundings, IR satellite imagery	Apr 06	July 06 ( <i>Oct 06</i> )	Completed
	Data Analysis	May 06	Aug 06 ( <i>Oct 06</i> )	Completed
	Final report	Aug 06	Sep 06 ( <i>Jan 07</i> )	Delayed to wait for NASA approval to distribute report
Situational Lightning Climatologies for Central Florida: Phase II	Modify code and develop algorithms needed to create climatologies	Nov 06	Mar 07	On Schedule
	Calculate number of lightning strikes in all boxes and output one value for each circle size for each flow regime	Mar 07	May 07	On Schedule
	Final memorandum	May 07	Jun 07	On Schedule
Anvil Forecast Tool in AWIPS	AWIPS training at GSD	Jul 05	Nov 05 ( <i>Apr 06</i> )	Ongoing as needed
	Develop software for calculation and display of anvil threat corridor	Dec 05	Apr 06 ( <i>Oct 06</i> )	Completed - Delayed due to delay in training
	Test and evaluate performance of the software	Apr 06	May 06 ( <i>Jan 07</i> )	Delayed as above
	Final memorandum	May 06	June 06 ( <i>Feb 07</i> )	Delayed as above

AMU Project Schedule 31 January 2007				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (New End Date)	Notes/Status
Volume-Averaged Height Integrated Radar Reflectivity (VAHIRR)	Acquisition and setup of development system and preparation for Technical Advisory Committee meeting	Mar 05	Apr 05	Completed
	Software Recommendation and Enhancement Committee meeting preparation	Apr 05	Jun 05	Completed
	VAHIRR algorithm development	May 05	Oct 05 (Jul 06)	Completed – Delayed due to new code development made necessary by final product requirements
	ORPG documentation updates	Jun 05	Oct 05 (Sep 06)	Completed – Delayed as above
	Configure ORPG and AWIPS system in the AMU for live data testing.	Oct 05	Jan 06 (Feb 07)	Delayed as above
	Preparation of products for delivery and memorandum	Oct 05	Jan 06 (Feb 07)	Delayed as above
WRF Model Sensitivity Tests	Identify candidate convective initiation days and archive data	Jul 06	Sep 06	Completed
	Configure LAPS to initialize WRF	Aug 06	Oct 06 (Jan 07)	Delayed due to satellite data conversion issues
	Compare LAPS-WRF vs. ADAS-WRF performance	Aug 06	Jan 07	On Schedule
	Compare use of high-resolution grid with 2-way, 1-way, and no nesting	Jan 07	Mar 07	On Schedule
	Assess impact of soil moisture data on WRF performance	Feb 07	Apr 07	On Schedule
	Final report and recommendations	Apr 07	Jun 07	On Schedule

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